# Studies of (Pb,La)(Zr,Sn,Ti)$O_3$ antiferroelectric single crystal with high electrocaloric effect

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## Abstract

Solid-state refrigeration and cooling technologies are important issues in modern society, with the increasing number of new energy sources and heat-generating devices. Several promising technologies are under development such as magnetocaloric and electrocaloric cooling. The major advantage of electrocaloric cooling over the magnetocaloric cooling is in the fact that the high electric fields required are much easier and less expensive to generate than the high magnetic fields required for the refrigeration cycle. (Pb,La)(Zr,Sn,Ti)$O_3$ (PLZST) is a promising candiate with unique field-induced phase transitions between FE and AFE which possessed excellent electrocaloric effect. In this work, we report unusual double negative ECEs and coexistence of the negative and positive ECEs in PLZST single crystals. A negative ECE value of -3.6 °C and enhanced electrocaloric strength of 0.3 K mm/kV have been obtained. The design strategy of having orthorhombic AFE and tetragonal AFE phase structures in one material in an appropriate temperature range is the key for these unusual effects. The double negative responses and the coexistence of the both negative and positive effects in one material are promising for next generation high efficient cooling devices. Our results will help people understand better the electrocaloric family, particularly on the negative and/or positive effect in antiferroelectrics and ferroelectrics.

## Image

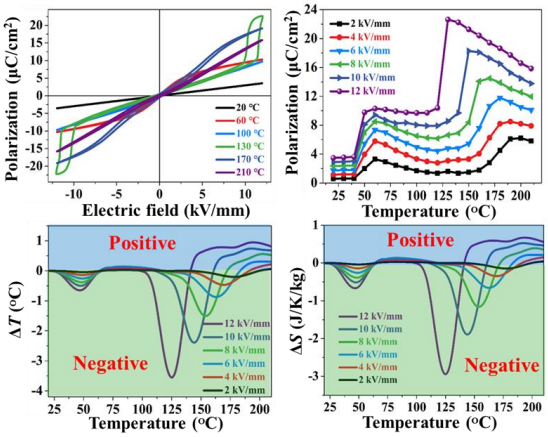



Fig. 1. Polarization and electrocaloric effect in PLZST single crystal.

## Recent Publications

1. Zhuo F.P., Li* Q., Zhou Y.M., Ji Y. J., Yan Q.F., Zhang Y. L., Xi X.Q., Chu X. C., Cao W.W., Large field-induced strain, giant strain memory effect, and high thermal stability energy storage in (Pb,La)(Zr,Sn,Ti)$O_3$ antiferroelectric single crystal. Acta Materialia, 2018, 148, 28-37.
2. Zhuo F P, Li* Q., Yan Q F, Zhang Y L, Wu H H, Xi X Q, Chu X C, Cao W W., Temperature induced phase transformations and negative electrocaloric effect in (Pb,La)(Zr,Sn,Ti)$O_3$ antiferroelectric single crystal. Journal of Applied Physics, 2017, 122, 154101.
3. Zhuo F.P., Li* Q., Qiao H.M., Yan Q.F., Zhang Y.L., Xi X.Q., Chu X.C., Long X.F., and Cao W. W.. Field-induced phase transitions and enhanced double negative electrocaloric effects in (Pb,La)(Zr,Sn,Ti)$O_3$ antiferroelectric single crystal. Applied Physics Letters, 2018, 112:133901.
4. Li Y.Y., Li* Q., Yan Q.F., Zhang Y.L., Xi X.Q., Chu X.C., and Cao W.W., Phase transitions and domain evolution in (Pb, La)(Zr, Sn, Ti)$O_3$ single crystal, Applied Physics Letters，2012, 101, 132904.
5. Luo N.N., Li Y.Y., Xia* Z.G., and Li* Q., Progress in lead-based ferroelectric and antiferroelectric single crystals: composition modification, crystal growth and properties, CrystEngComm, 2012, 14(14), 4547-4556.



Prof. Qiang Li graduated from Dept. of Material Science & Engineering, Shanghai Jiao Tong University in 1985, and received his Ph.D in the State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology in 1993. He moved to the Department of Chemistry, Tsinghua University, as a full professor in materials chemistry, in 2000, from Wuhan University of Technology. His research interests were mainly focused on crystal materials & crystal growth, ferroelectric (anti-ferroelectric) materials and related functional materials etc.

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